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TETRA versus DMR

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Introduction

This white paper considers the performance, functionality, applications and interoperability aspects as well as the migration strategies for both the TETRA and DMR standards.

The European Telecommunications Standards Institute (ETSI) created both the TETRA and DMR standards. A large number of manufacturers and end users have participated in working groups to create requirements and to craft the specifications that are the basis for both standards. In principle both DMR and TETRA are open standards, although some implementation details, particularly in DMR, are left open to allow proprietary extensions by manufacturers.

TETRA is a mature, feature rich and well-supported standard that has become the technology of choice for mission and safety critical communications. Large nationwide and regional networks for public safety are in operation today, as well as thousands of smaller on-site or regional networks for a wide range of applications, including public transport, oil & gas, airports and seaports, utilities and industry. TETRA is now in operation in over 120 countries in the world, and millions of radios have been sold since the introduction of TETRA in 1997.

DMR was launched in 2005 to meet the requirements for business and industry. The first products were aimed at Tier II repeater operations as a direct replacement for analogue conventional radio repeaters. A large number of single site repeaters and reasonable number of simulcast networks have been installed since the first products were introduced in 2007. The first Tier III products were launched in 2012 aimed to replace analogue (i.e. MPT-1327) trunking radio systems.

Although DMR is sometimes seen as a threat to TETRA in certain markets, the standards are mainly complementary. A good understanding of the benefits and limitations of both standards is therefore essential to make the right choice when migrating any analogue radio network to the digital world. The goal of this white paper is to examine the claims of both TETRA and DMR proponents to find out what is really relevant for any application.

Performance

Performance aspects are mainly related to spectrum efficiency, data throughput, power efficiency and coverage.

Spectrum efficiency and data throughput

On first glance, the spectrum efficiency of TETRA and DMR is equal: TETRA offers four voice channels (timeslots) per 25 kHz of spectrum, whereas DMR offers two voice channels per 12.5 kHz channels. Both standards thus require 6.25 kHz of spectrum per voice channel.

The more advanced TETRA standard does however provide a number of distinctive advantages:

- For IP packet data services, DMR offers a throughput of 2.0 kb/s per timeslot, whereas TETRA offers 3.5 kb/s per timeslot. TETRA thus offers 75% more capacity for the same spectrum size. In addition, TETRA offers multi-slot packet data, increasing throughput to 4 x 3.5 = 14 kb/s, a sevenfold increase in comparison with DMR.
- A single TETRA transceiver supports four logical channels, enabling up to three different groups to communicate simultaneously in addition to a control channel. In comparison, DMR offers two logical channels per transceiver in Tier III trunked mode, providing capacity for just one group call in addition to the control channel. Although it is possible to operate DMR in non-dedicated control channel mode, some services will then not be available on the DMR radios operating in that area when the control channel is used for traffic instead, including the ability to roam or setup calls.

TETRA thus offers significant more capacity and versatility with the same amount of spectrum, enabling growth of voice and data traffic beyond the limitations of DMR.

Power efficiency

TETRA and DMR trunked operation both require continuous control channel availability on every base station to allow roaming and handover, as well as continuous ability to setup emergency calls and to transmit and receive data and status messages. Just switching off the transmitter to save energy is thus not relevant for both TETRA and DMR trunked operation.

Power saving techniques to switch off unused carriers in TETRA are already commonplace and have been available since the first deployed TETRA networks. Recently, TETRA infrastructure manufacturers have implemented enhanced power saving techniques by disabling output power on a per-slot basis when these are not used for traffic channels. So far techniques to switch off the transmitter on a per-slot basis have not been implemented in DMR base stations.

An advantage of DMR in terms of energy consumption is the fact that simpler, more efficient Class C power amplifiers (PAs) can be used. TETRA requires highly linearised PAs that are not as efficient as those used by DMR. On the other hand, special linearisation techniques have been implemented to improve the efficiency of a TETRA capable PA making it close to the efficiency of a DMR PA. A positive side effect of linearisation is superior power control and performance for reduced output power compared to Class C power amplifiers.

TETRA has the advantage of providing double the traffic channel capacity per base station transceiver. The equivalent of one TETRA transceiver is two DMR transceivers with a branching system (combining and receiver multi-coupler), which is obviously costlier for DMR and half as power efficient compared to TETRA due to the losses in the combining equipment.

Thanks to innovations in technology, TETRA is thus more power efficient when compared to DMR today, possibly with the exception of when the capacity of a single DMR transceiver is sufficient.

Spectrum and coverage

Both TETRA and DMR are designed to operate side-by-side with analogue radio channels to allow co-location of digital radio networks in existing bands for analogue PMR. This requires a strict level of adjacent channel power and selectivity that is comparable with analogue transceivers; much unlike cellular standards such as GSM and CMDA, which require a guard band to prevent interference. Spectral pollution of TETRA is thus at least equal to DMR, and coverage is certainly not expected to degrade due to interference.

TETRA specifies that C/I (co-channel interference) is to be measured under dynamic conditions. This contrasts with DMR which is measured under static conditions and so can appear to have better C/I performance. The reality is that when TETRA is measured under static conditions its performance is at least as good as that for DMR. Network planning and coverage will therefore be similar for both.

Availability of two or three channel diversity in TETRA base stations helps to further increase coverage. This feature is not available in most DMR base stations, and improves receiver sensitivity by 5 to 8 dB in areas where multipath fading occurs and there is an even higher improvement if a greater number of receivers is used.

The laws of physics dictate a better coverage for VHF bands when compared to UHF bands so DMR on VHF offers a coverage advantage compared to TETRA on UHF that is especially interesting for low-density networks. However, it is expected that TETRA equipment will soon become available in VHF as well, as ETSI has recently published the standard for VHF support of TETRA, and multiple suppliers have declared their support.

It should also be noted that DMR base stations and radios with higher output power are available, which is also beneficial for low-density networks.

Interoperability

TETRA owes its success in a large part to the availability of systems and radios of several vendors that are interoperable. This open standard, multi-vendor approach has resulted in a highly competitive market with solutions targeted at a large number of market segments.

The TETRA Interoperability process (IOP) has unmistakably contributed to the development of TETRA into a truly open multi-vendor standard. The TETRA IOP is a continuous process embracing all new features that come to the market, and is reassuringly comprehensive with over 1000 test cases covering all essential services. The TETRA IOP process is truly independent, and is accepted globally as a highly professional process.

No other digital technology has such a well defined, independently monitored, comprehensive interoperability process that encompasses all of its features.

Users can expect radios from different manufacturers to fully interwork on any manufacturer's TETRA network. When inviting tenders, the contracting authority may therefore choose from a large number of vendors for both infrastructures and radios, which has a positive effect on the price of the total solution and leads to less dependence on a specific vendor. The resulting healthy competition also results in more innovation in both networks and terminal products.

Whether DMR will achieve the same interoperability result is doubtful: the DMR standard does not specify a number of components and functionalities, including the speech vocoder and encryption options, and allows for manufacturer-specific proprietary extensions, including Tier III trunked radios and networks. Although the DMR proponents may suggest that DMR radios and networks of different brands can work together, proven by interoperability testing, in reality this is only the case for basic functionalities and still allows for many proprietary implementations.

While vendor lock-in is not visible at first glance when purchasing a complete DMR solution with terminals included, users will be disappointed to find themselves dependent on a single supplier when purchasing additional radios. This is due to specific vendors owning proprietary features based on IPR which are not made available to other vendors.

Functionality and Applications

TETRA is undoubtedly suitable and adopted worldwide for **mission-critical applications**, including public safety, security and local government. High availability by means of redundant equipment and links, instant call setup and an extensive feature set for mission-critical communications are relevant here.

For **safety-critical applications**, which include petrochemical industry, oil & gas, mining and signalling for public transportation, TETRA also has a leading edge over DMR due to TETRA solutions with high availability features, higher data throughput for telemetry and data applications, and an extensive feature set.

Business-critical applications can benefit from advanced functionalities and higher data throughput. Examples are public transport, airports and seaports, utilities and industry.

The following table provides an overview of available functionalities in TETRA and DMR. In addition, the importance of each feature for specific applications is listed.

Functionality	TETRA	DMR	Public safety	Public transport	Airports & seaports	Oil & Gas	Utilities	Industrial	Commercial
Group call	√	√							
Group scanning	√	√							
Individual call, simplex	√	√							
Individual call, full-duplex	√	- [1]							
Telephone call, semi-duplex	√ [3]	√							
Telephone call, full-duplex	√	- [1]							
Short Data Service	√	√							
Status Messaging	√	√							
Packet Data	√	√							
Location services	√	√ [2]							
Broadcast call	√	√							
All call	√ [3]	√							
Open voice channel mode	√ [3]	√							
Priority call	√	√							
Pre-emptive emergency call [4]	√	√							
Dynamic Group Number Assign.	√	-							
Enable / Disable, Stun & Revive	√	√							
Permanent Disable, MS Kill	√	√							
Authentication	√	√							
Mutual authentication	√	-							
Air interface encryption	√	- [2]							
End to End Encryption	√	- [2]							

Relevance for application	High	Medium	Low	Not

Notes

1. Possible in theory but requires more advanced DMR transceiver design, not available in the current generation of DMR radios.
2. Proprietary (vendor specific) solutions are available, but may evolve soon in standards-based solutions.
3. Not available in all TETRA infrastructure solutions.
4. TETRA offers more powerful pre-emption and emergency calling capabilities, including priority group scanning, pre-emptive speech item request, subscriber pre-emption, resource pre-emption and call modification on emergency call.

The choice of mobile or handheld radios for specific applications is of significant importance. Specialised equipment and/or advanced features can really add value to a TETRA or DMR solution. The following table provides an overview of available features in TETRA and DMR radios, and how relevant these are to the listed applications.

Radio feature	TETRA	DMR	Public safety	Public transport	Airports & seaports	Oil & Gas	Utilities	Industrial	Commercial
Voice + data terminal	√	√							
Data-only terminal [1]	√	√							
Direct Mode	√	√							
Direct Mode Repeater	√	-							
Direct Mode Gateway	√	-							
Water proof, e.g. IP54	√	√							
Intrinsic safe / ATEX approved	√	√							
Man Down	√	√							
High-res colour screen	√	√							
JAVA applications	√	-							
Integrated web browser	√	-							
Built-in GPS receiver	√	√ [2]							
Bluetooth	√	-							

Relevance for application	High	Medium	Low	Not

Notes

1. Examples include data terminals for SCADA (Utilities, Oil & Gas), remote metering (Utilities) and signage (Public transport). Users of TETRA benefit from higher packet data throughput.
2. Proprietary (vendor specific) solutions are available, but may evolve soon in standards-based solutions.

Migration aspects

Options for migration of analogue to digital are often restricted due to the severely limited availability of radio spectrum, especially when multi-site networks have to be deployed. In addition, trunked radio mostly requires a continuous chunk of licensed spectrum in which no interference is expected within the operating area.

In most countries, specific spectrum is reserved for trunked radio operation, mostly in the 400 MHz and 800 MHz UHF bands. VHF frequency bands are mostly reserved for single-site PMR repeater operations, which is exactly the objective of Tier II DMR systems. However, there are some existing analogue trunked radio networks (like MPT-1327) operating in VHF frequency bands.

Despite concerns on interference, VHF may be the appropriate choice for multi-site networks. One example is simulcast radio networks, addressing the requirement of extremely low-density voice communications covering a large operating area. This is where DMR might be the right choice.

Interoperability with existing networks

Backwards compatibility is another consideration when trying to simplify migration to a new network. At first glance ideally, it should be possible to continue the use of existing analogue radios on the new network, and after full installation and commissioning of the new network to migrate the radios to the new network as well. But looking over the entire life of a new radio network, which typically would be more than 15 years, it is very important that the potential efficiencies that can be gained by implementing and optimising new working practices are considered right from the outset.

DMR is using technology that is closely related to analogue transceiver technology. In fact, many DMR Tier II repeaters and radios are supporting both analogue and digital operation, allowing gradual migration from analogue to digital.

However, this dual-mode operation is not applicable to DMR Tier III trunked operation, while the existing conventional radios are not compatible with DMR trunked radio protocols. Also, there is no gradual upgrade path of networks from any of the existing analogue trunked radio protocols (e.g. MPT-1327, LTR, Smartnet) towards DMR Tier III. It should be noted that some DMR manufacturers supply dual-mode Tier III terminals supporting both MPT-1327 and DMR to ease migration, but then the network owner is forced to buy these specific terminals before gradually migrating to DMR.

A common solution to achieve interoperability with existing analogue radio networks is to deploy gateways between the existing analogue and new digital networks. Virtually all TETRA network suppliers provide gateways to analogue radio, which support interoperability with both conventional and trunked radio networks. This enables a user to leap from a voice centric operation to an information centric operation by making full use of the advanced features of TETRA.

Re-use of existing site facilities

Options to re-use existing site facilities need certainly to be investigated in order to reduce capital expenditure. This includes the re-use of site shelters or buildings, antenna masts, antennas, cabling and the transmission network.

Re-use of the site location is possible when the expected coverage of the new digital base station is at least as good as the existing analogue base station, which is the case for both DMR and TETRA when the same frequency band is adopted. Antenna masts may also be re-used, in addition to antennas and cabling if the remaining lifetime of these components is sufficient.

Although one can argue that existing RF combining equipment and power supplies may be re-used for DMR, this is often not attractive due to the superior performance and smaller size of new equipment. Advances in the power efficiency of modern equipment can have a beneficial impact on cooling, battery back-up and site rental costs hence making the total cost of ownership of new equipment significantly lower than if existing equipment is re-used.

Re-use of the existing transmission network is rarely an attractive proposition. In the past, multi-site trunked radio networks were using either analogue leased line interconnections or digital (fractional) E1 / T1 circuits that are both very expensive in operation. TETRA and DMR can operate over IP links or E1 / T1 circuits if for commercial reasons they need to be retained. In which case it should be noted that they will use much less bandwidth, which is typically one-quarter of the bandwidth required for an analogue link. Multiplexed audio lines or slow modem connections over copper wire are not suitable for building DMR Tier III networks, and TETRA does not require more link capacity for voice, data and signalling compared to DMR.

Deployment and operation

Today, the architecture of TETRA networks is much simplified compared with (say) five years ago. Understanding, managing and configuring a single-site or regional TETRA network does not require highly skilled specialists or supplier assistance anymore, thanks to advances in technology such as all-IP networks and soft switch architectures. Of course, training of technical staff is still mandatory, but the “complexity” is equal to DMR Tier III.

Conclusion

TETRA is a mature and well defined standard which is kept up to date with a programme of continuous development and enhancement. TETRA suppliers are now delivering their third-generation solutions with advanced functionalities that are easy to install and operate, highly reliable and affordable.

TETRA offers scalability and performance way beyond DMR. Specifically the data throughput and voice capacity of TETRA are relevant for many safety and business critical applications, such as public transport, utilities and airports.

With the arrival of small TETRA solutions for industry and commercial applications, even the most cost constrained applications like construction, private security, retail, hospitality and warehousing can benefit from TETRA.

In terms of operational cost it is highly relevant that all TETRA functionality is based on open standards, ensuring interoperability of radios and networks from different suppliers, also if these are purchased after the initial order. Vendor lock-in is not applicable, and buyers can benefit from a rich ecosystem of specialised radio equipment and applications.

Basically, simulcast networks and Tier II VHF repeater operations are the only unique selling points of DMR, for which it is not possible to find an equivalent TETRA solution.